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ABSTRACT

This module expands on the concepts of cost estimation and comparison of costs among various treatment alternatives which were presented in a previous module. The need for useful published cost data is stressed. Criteria for selecting cost references are presented, and examples of charts and graphs from several of these are used in comparing land application and conventional treatment schemes. Several critical cost factors are identified. A summary of generalized cost comparisons is made. Several pertinent cost references are listed, and the importance of keeping up to date with new reference material is pointed out to land treatment site designers. (Author/BB)

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# Land Application of Wastes

An Educational Program

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COSTING LAND APPLICATION SYSTEMS

Module 10

January, 1978

SE 025 024

## LAND APPLICATION OF WASTES - AN EDUCATIONAL PROGRAM

The objective of this program is to increase the knowledge of engineers, scientists, waste management specialists and other practitioners in the concepts and principles needed to properly utilize the potential of land for the application of wastes. It is designed for individuals concerned with waste disposal alternatives for municipal, industrial, and agricultural wastes. The modules in this Program incorporate knowledge from sanitary and environmental engineering, agronomy, soil science, agricultural engineering, economics, and law.

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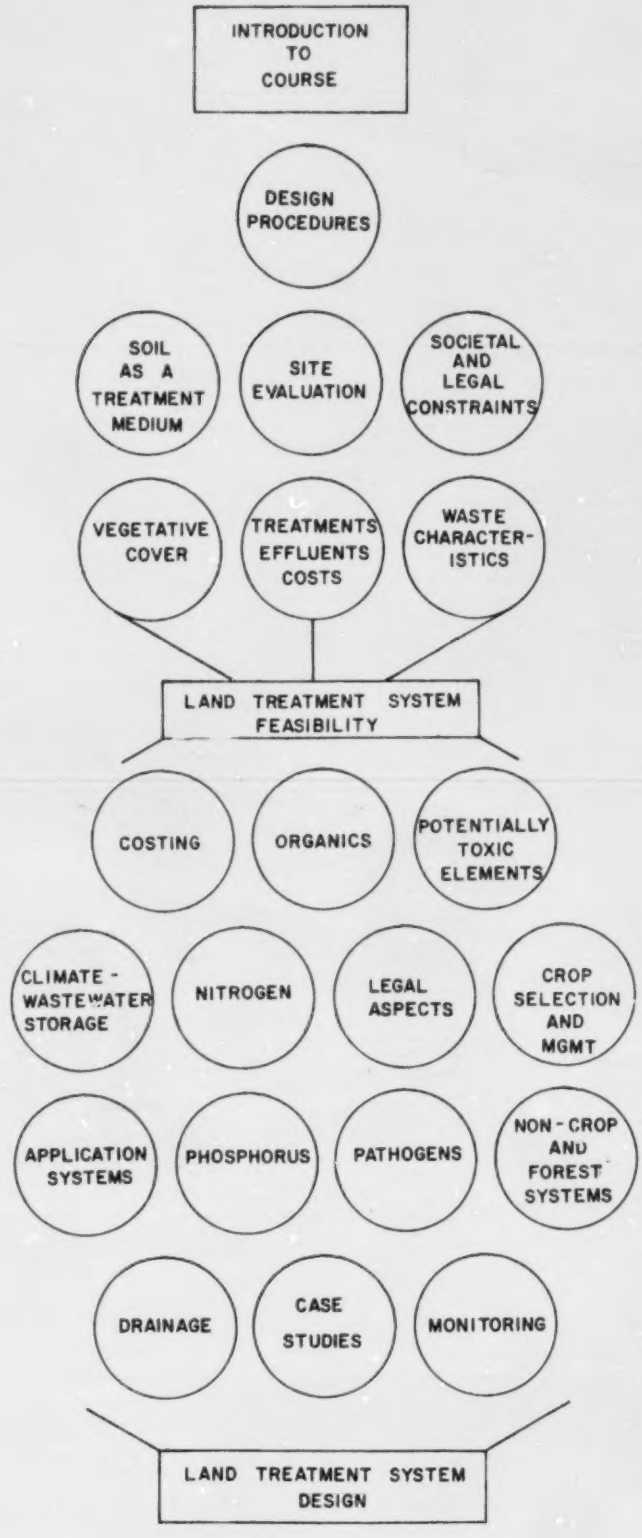

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## Summary

This module expands on the concepts of cost estimation and comparison of costs among various treatment alternatives which were presented in Module 4, "Treatment Systems, Effluent Qualities, and Costs".

The need for useful published cost data is stressed in this module. Criteria for selecting cost references are presented, and examples of charts and graphs from several of these are used in comparing land application and conventional treatment schemes.

Several critical cost factors, referred to here as "breakpoint issues" are identified, each of which can exert a large influence on land application feasibility. A summary of generalized cost comparisons is made. Several pertinent cost references are listed, and the importance of keeping up to date with new reference material is pointed out to land treatment site designers.

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## Objectives

Upon completion of this module, the reader should be able to:

1. Define and discuss at least three "break point" issues of importance in evaluating cost-effectiveness of land application systems.

2. Give the range of sludge handling costs as a percentage of conventional treatment costs for the treatment systems discussed.

3. Use several of the available cost references to make comparisons between conventional and land application systems.

## Introduction

In Module 4, "Treatment Systems, Effluent Qualities, and Costs", an effort was made to emphasize how site specific needs in waste treatment are met through the selection of system components. It was pointed out that various permutations of system components were possible and that it was the option of the designer to select appropriate components and integrate them into a functional system.

However, that very flexibility of design options creates severe difficulties in formulating costing estimates. The number of options available to handle site specific problems is great. Specific cost listings for each option become impractical. Thus, the objective of this module is to give the reader some general insights into relative costs and introduce some costing literature and representative problems.

Limitations of this Module:

There are two significant limitations imposed on this module.

1. Discussions are to be confined only to selected, exemplary systems.
2. Published costing information is scarce, usually dated, and sometimes contains uncommon units or information that is difficult to interpret and compare with other publications.

Clearly, these two factors make a general discussion of the subject difficult.

Criteria for Selecting Literature:

The literature selected for this module was accepted with the following reservations:

1. While the data, tables, graphs, and accompanying values are realistic representations of costing information, all values are considered to be out

of date. No attempt is made here to update them. The method usually used by designers to update cost data is the "cost index", which may be used on any cost figures for which the date of development is known. A cost index is computed using known inflation rates for labor, materials, and other components of construction project costs, and related to a standard value at some past date. Two indexes are recommended:

a. The ENR cost index is a measure of general heavy construction costs. It is printed periodically in Engineering News - Record magazine and is figured for selected cities around the U.S.

b. The EPA construction cost index covers construction costs related to wastewater treatment, storage, and conveyance systems. It is also periodically updated and varies from city to city. This index is divided into the Sewage Treatment Plant C.C.I. and the Sewer C.C.I.

In order to determine the most up-to-date rates for labor, materials, and other construction needs, two indexes should be consulted: Engineering News - Record magazine and the Sewage Treatment Plant C.C.I. - Sewer C.C.I. of the EPA.

2. The most useful information (for the purposes of this module) is comparative costs between systems rather than the dollar-and-cents costs of a specific system. It is assumed that relative costs will remain more stable despite changes in absolute costs.

3. References used in this module were selected because:

   a. They represent typical presentations of costing information and are assumed to reflect close approximations to the "real world".

   b. They are readily available to designers across the country.

c. They have much explanatory, relevant information a reader may wish to explore on his own time.

d. Readers will often have professional access to other costing information preferred by their respective firms or governmental agencies and not necessarily available to the public or for reproduction here.

4. Only a very few of all available options of system design are considered. Those designs which have been selected are simply examples. No "favored" or "preferred" status is to be implied.

## General Overview of Relative Costs

In Module 4, "Treatment Systems, Effluent Qualities, and Costs", distinction was made between

- pretreatment (systems that partially renovate wastes before land application), and
- land application systems.

This module will emphasize that distinction. The major organization of the module is a division of costing information between pretreatment and land application. In this way, the cost of a total system can be estimated more easily as the sum of the costs of pretreatment and land application components.

### Comparing Components that Affect Costs

Before specific costs are considered, it may be useful to review something of the complexities of pretreatment and land application components.

An initial glance at Figures 1 and 2 shows that both pretreatment (Figure 1) and land application (Figure 2) are divided into a number of major component parts. Each of those parts is divided, in turn, into two or more units which may or may not be mutually exclusive.

The design of a given system will include a blending and matching of the appropriate component units given in Figures 1 and 2. The cost of the system, however, will be related to the complexity of the final system. Where at least secondary pretreatment precedes land application, the complexity of the system may become sufficient to defeat cost competitiveness with, say, tertiary treatment. This concept was emphasized in Module 4.

### Relative Cost of Pretreatment Varies with Complexity, Size of System

Pretreatment costs for wastewaters: To see the general picture of relative costs of wastewater pretreatment, turn to Figures 3 and 4. Comparative capital costs appear in

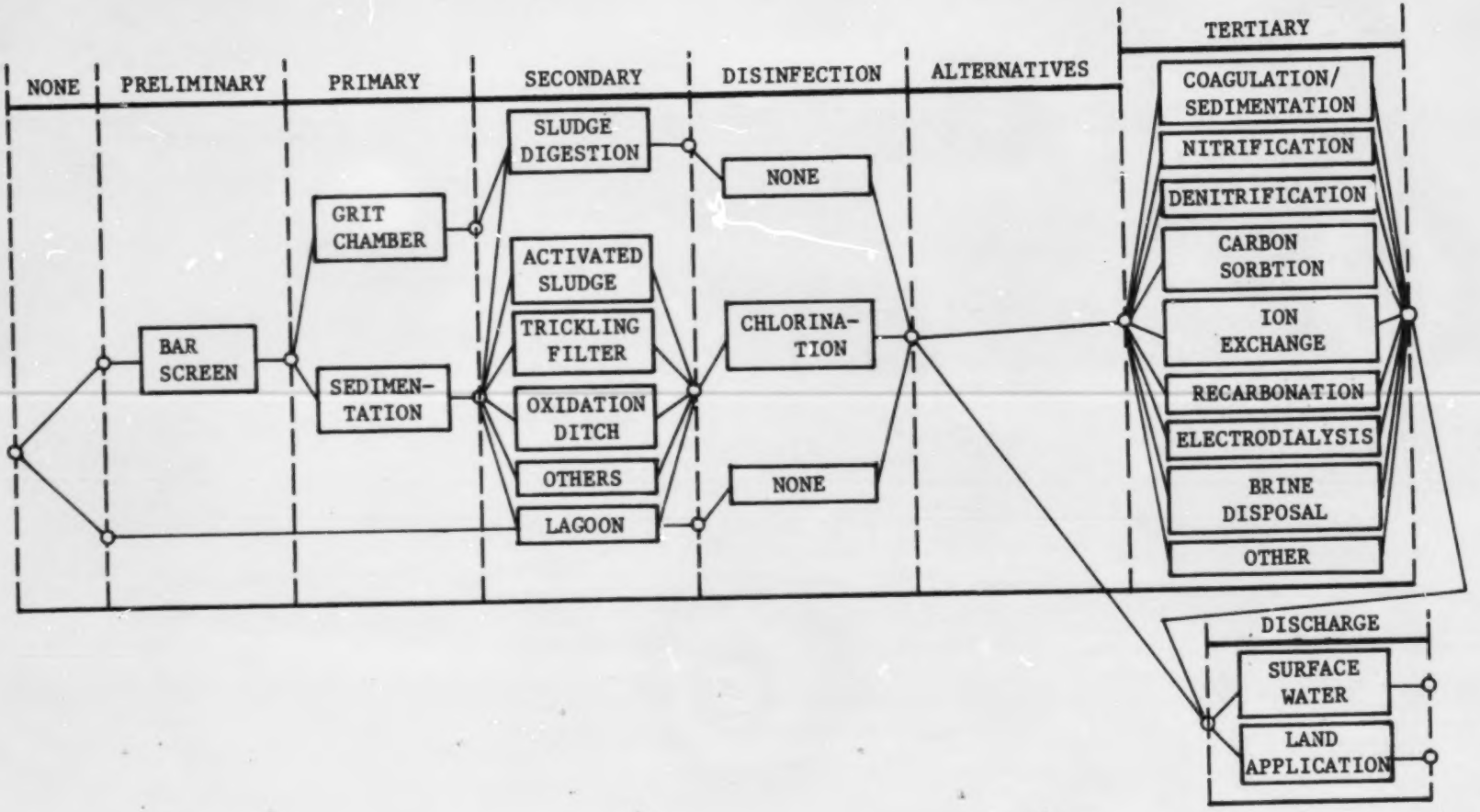



Figure 1. Pretreatment system components with tertiary treatment. Relationship of various components of sewage treatment systems not utilizing land application.

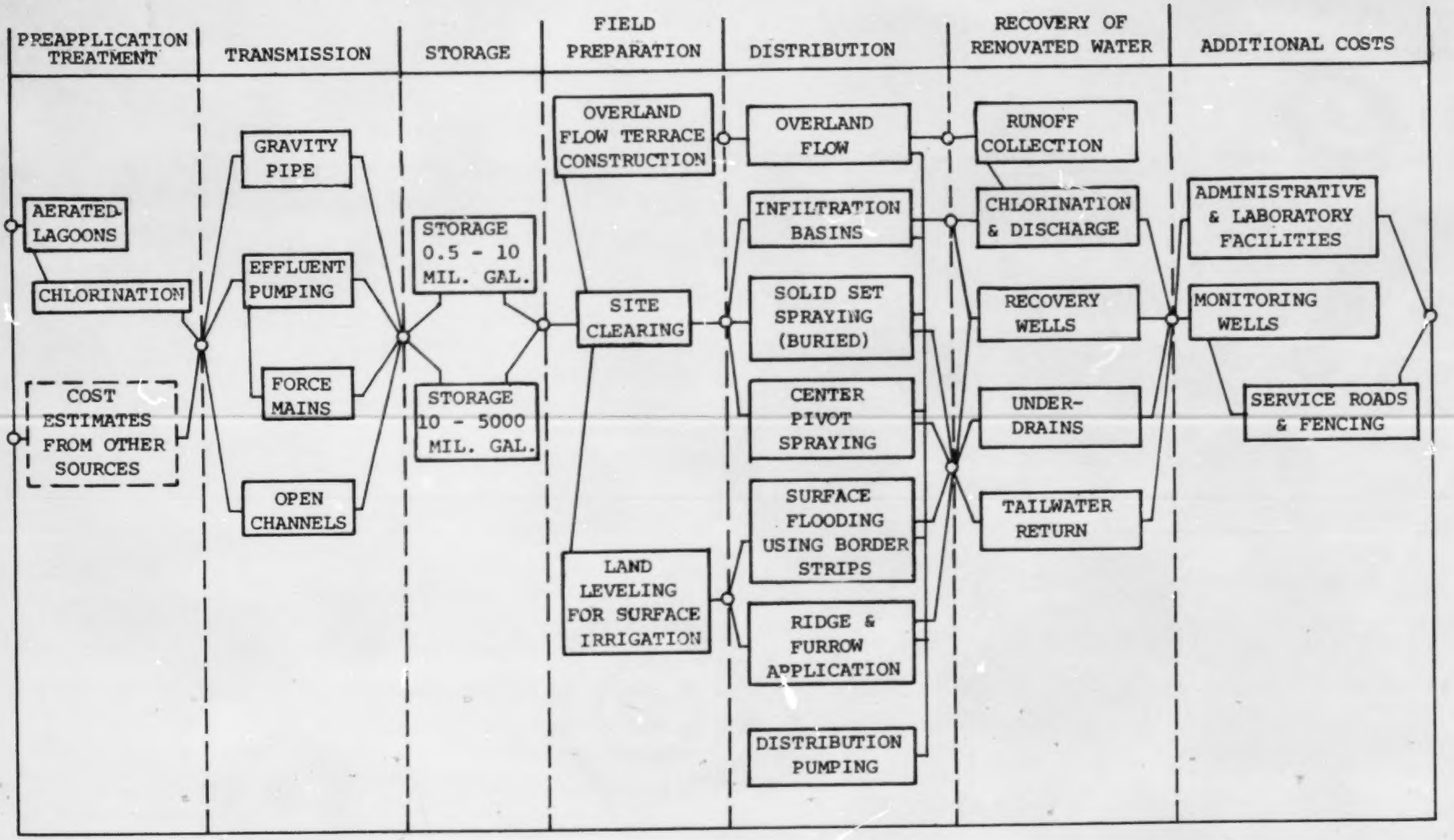



Figure 2. System components used in land application. Relationship of various components of sewage treatment by land application (from Pound, C.E., et al. 1975).

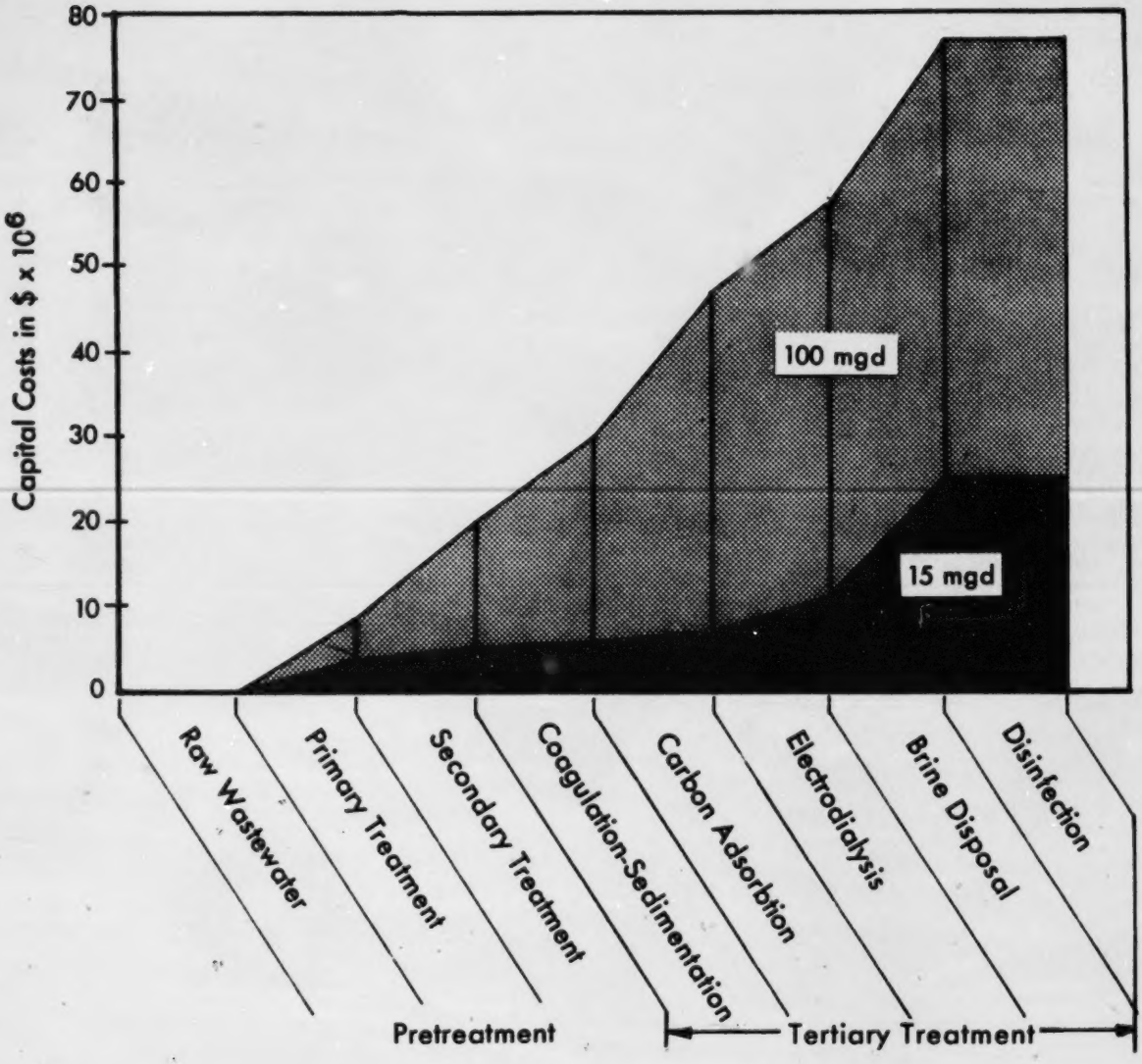



Figure 3. Cumulative capital costs.
Relative values for wastewater pretreatment of increasing complexity and tertiary treatment at two flow rates (adapted from Stephan and Weinberger, 1968).

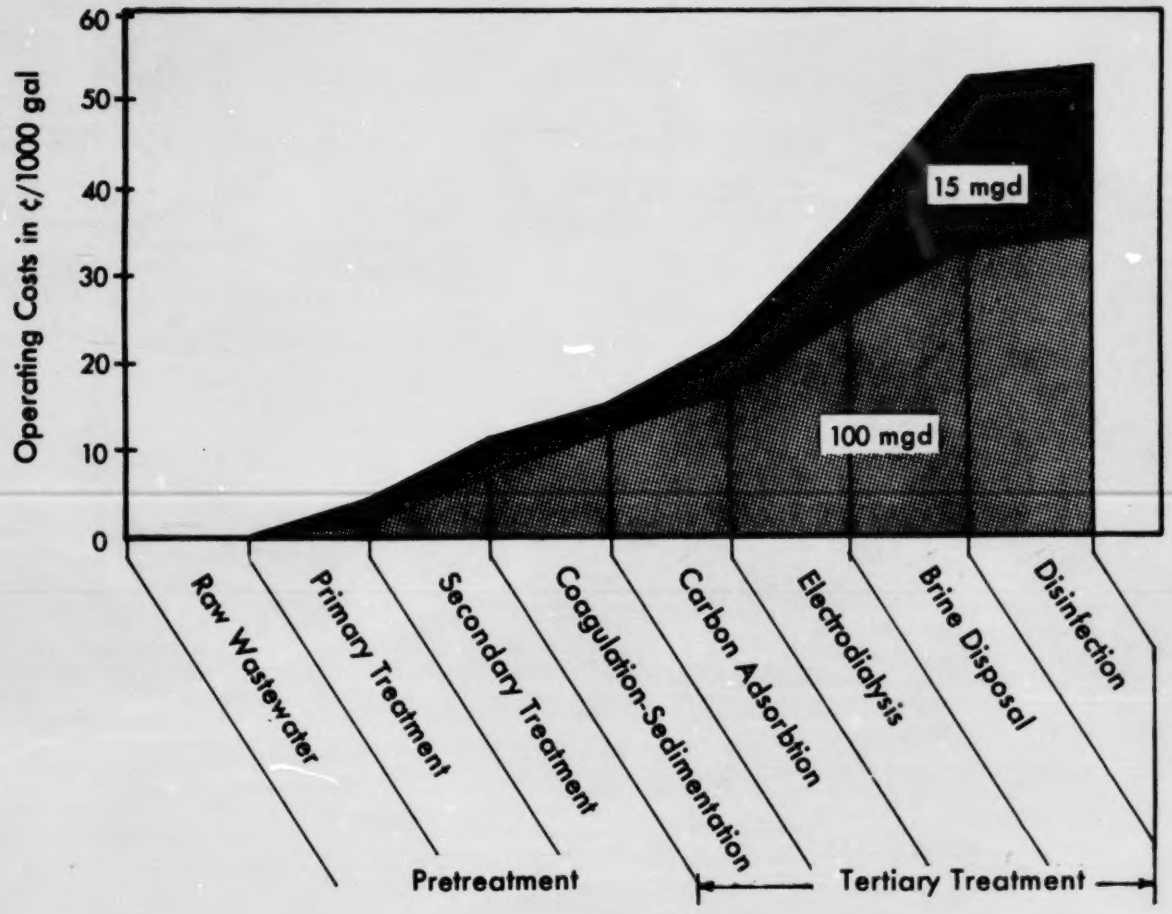



Figure 4. Cumulative operating costs.
Relative values for wastewater pretreatment of increasing complexity and tertiary treatment at two flow rates (adapted from Stephan and Weinberger, 1968).

Figure 3 and comparative operating costs appear in Figure 4. As expected, costs increase across the board as wastewater pretreatment complexities increase. But while capital costs (Figure 3) increase dramatically, especially for higher volume flows, relative operating costs are highest for smaller volume plants at any given level of pretreatment complexity. That trend is quite independent of the specific wastewater treatment employed.

Costs increase across the board as wastewater pretreatment becomes more complex; operating costs are highest for smaller volume plants.

Pretreatment costs for sludges: In general, costing for sludge treatment follows patterns remarkably different from those seen in wastewaters. First there is no apparent across-the-board trend.

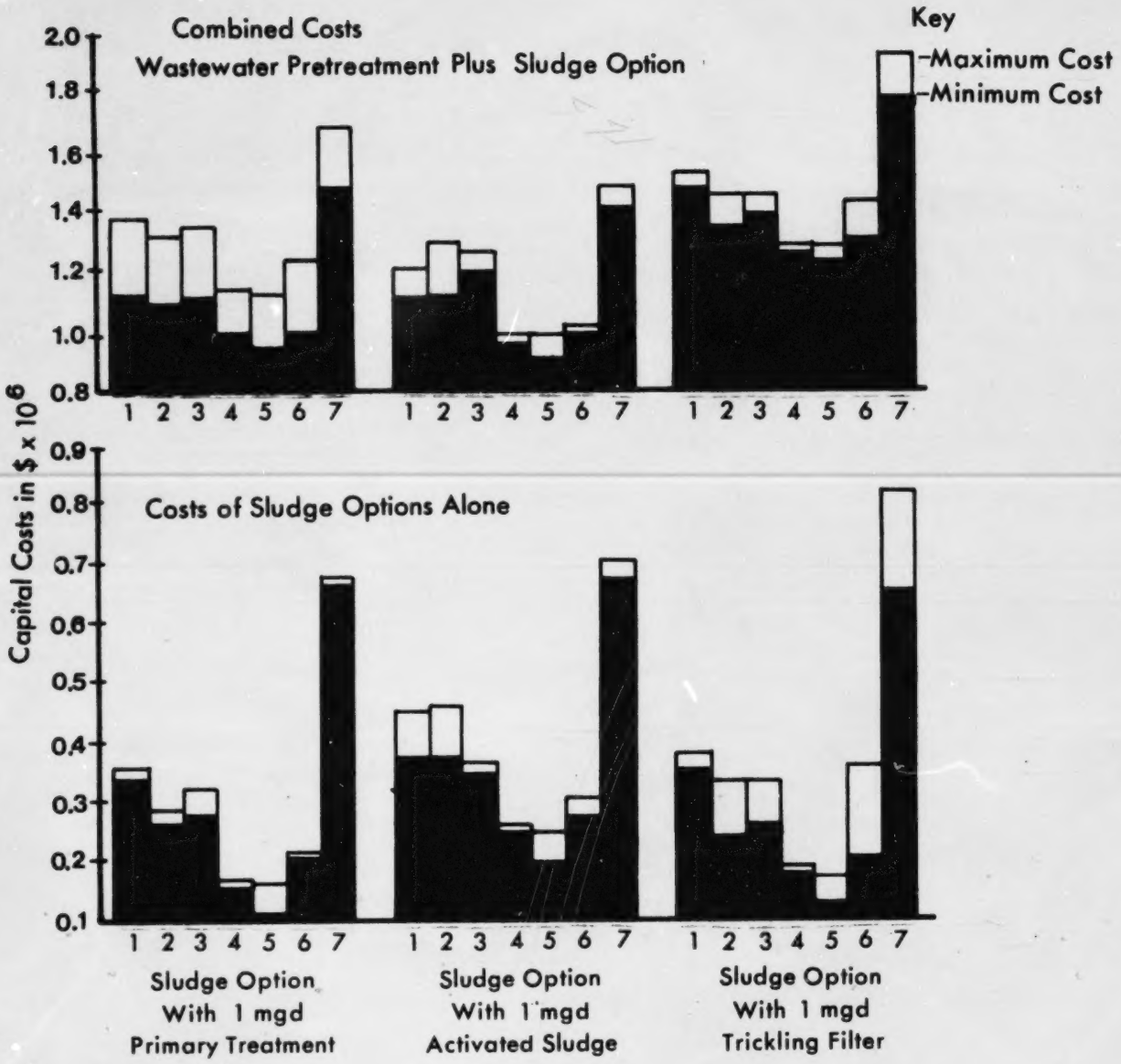
Secondly, sludge handling costs vary considerably depending on the design for wastewater treatment. The general complexity of estimating costs for sludge handling is illustrated in Figures 5 and 6.

Clearly, sludge handling represents a sizable fraction of pretreatment capital costs, ranging from roughly 10% (option 5, trickling filter) to 46% (option 7, activated sludge) for the 1 mgd facilities included in Figure 5. Operating costs represent about the same range (11% for option 5, primary treatment to 36% for option 1, activated sludge).

Sludge handling represents a sizable fraction of pretreatment capital costs.

Cost Comparison Between Pretreatment and Land Application

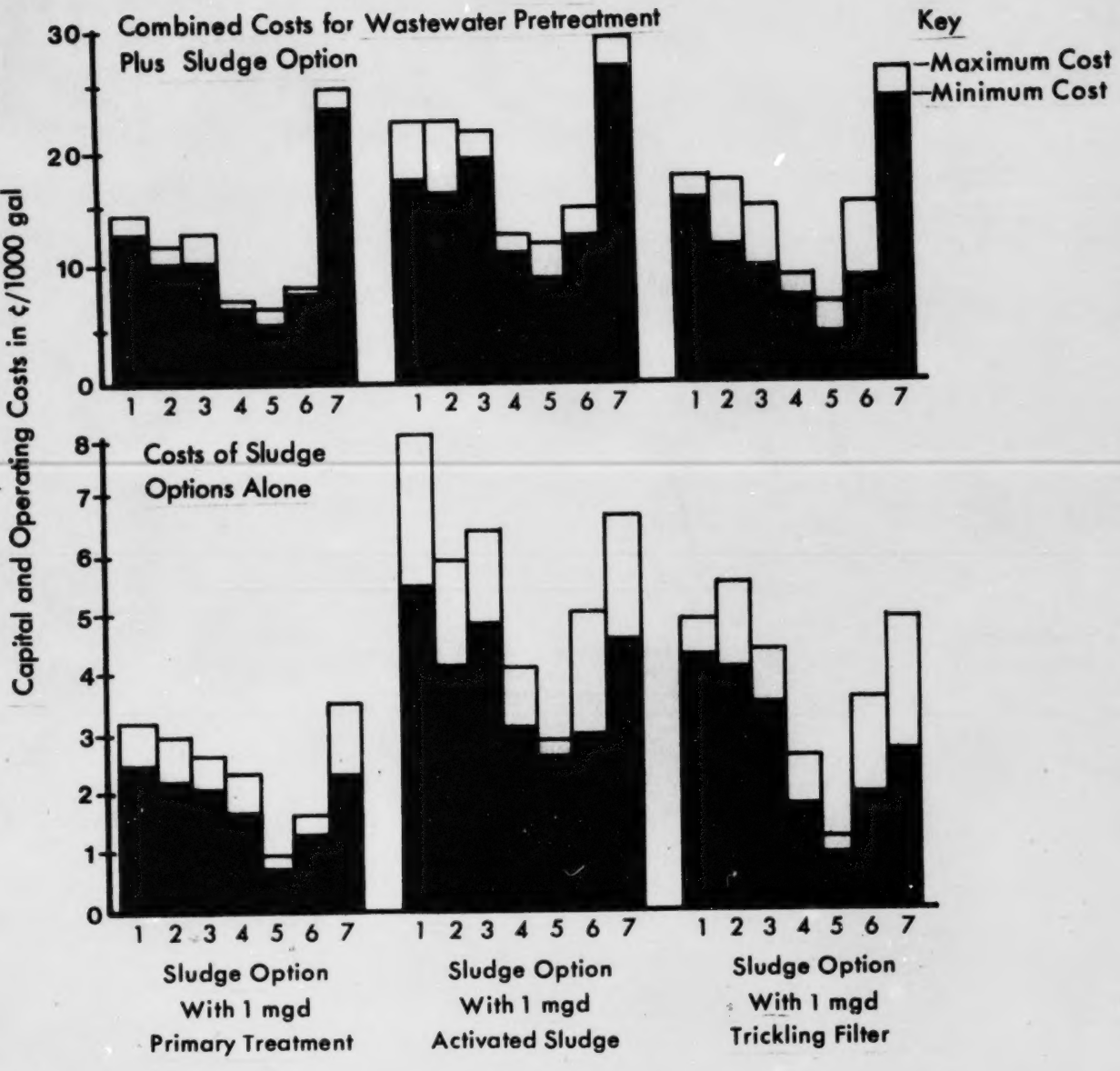
In general, capital costs for land application regimes are roughly equal to primary pretreatment. Operating costs range from the level of primary treatment to a value approaching that of trickling filter operation. This is illustrated in Figure 7 for 1 mgd flow rate. Land application costs in Figure 7 are independent of the pretreatment cost. As a rough rule-of-thumb, this pattern is consistent across most flow rates.




Sludge Options

1. Gravity, Chemical, Vacuum Filtration, Incineration, Landfill
2. Chemical, Centrifuge, Incineration, Landfill
3. Gravity, Porteous, Vacuum Filtration, Incineration, Landfill
4. Gravity, Digestion, Sand Drying, Landfill
5. Gravity, Digestion, Land Spreading
6. Gravity, Digestion, Vacuum Filtration, Landfill
7. Gravity, Digestion, Vacuum Filtration, Ocean Dumping

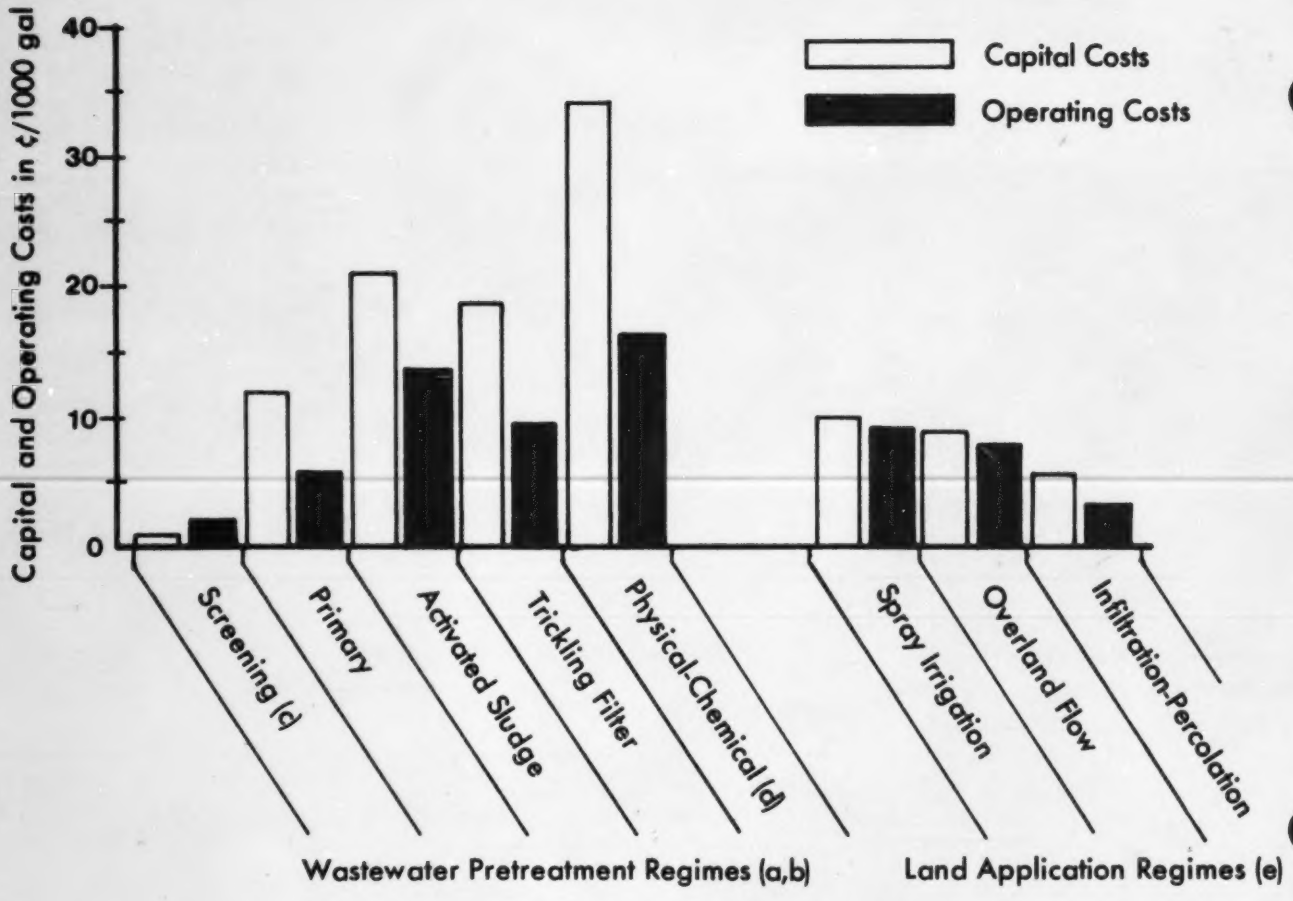
Figure 5. Comparative capital costs for selected sludge options occurring in conjunction with three wastewater pretreatment regimes (adapted from the Battelle Report, 1974).




Sludge Options

1. Gravity, Chemical, Vacuum Filtration, Incineration, Landfill
2. Chemical, Centrifuge, Incineration, Landfill
3. Gravity, Porteous, Vacuum Filtration, Incineration, Landfill
4. Gravity, Digestion, Sand Drying, Landfill
5. Gravity, Digestion, Land Spreading
6. Gravity, Digestion, Vacuum Filtration, Landfill
7. Gravity, Digestion, Vacuum Filtration, Ocean Dumping

Figure 6. Comparative operating costs for selected sludge options occurring in conjunction with three pretreatment regimes (adapted from the Battelle Report, 1974).




(a) Capital Cost at Sewage Treatment Plant Construction Cost (STPCC) Index 192.8, Amortized Over 25 Years at 7% Interest.

(b) Operating Costs Updated 192.8/119.1 = 1.62 Times Reported Costs

(c) Arbitrary 40 Mesh Screen (Water Resources Engineers, 1968)

(d) Coagulation-Sedimentation (Lime and Ferrous Sulfate) Plus Granular Carbon Adsorption Costs

(e) Estimated 1973 Dollars, Engineering News-Record Construction Costs (ENRCC) and STPCC Index 192.

Note: STPCC = Sewage Treatment Plant Construction Cost
ENRCC = Engineering News-Record Construction Cost

Figure 7. Relative costs in pretreatment and land application regimes for capital and operating expenses at 1 mgd flow (adapted from Pound and Crites, 1975).

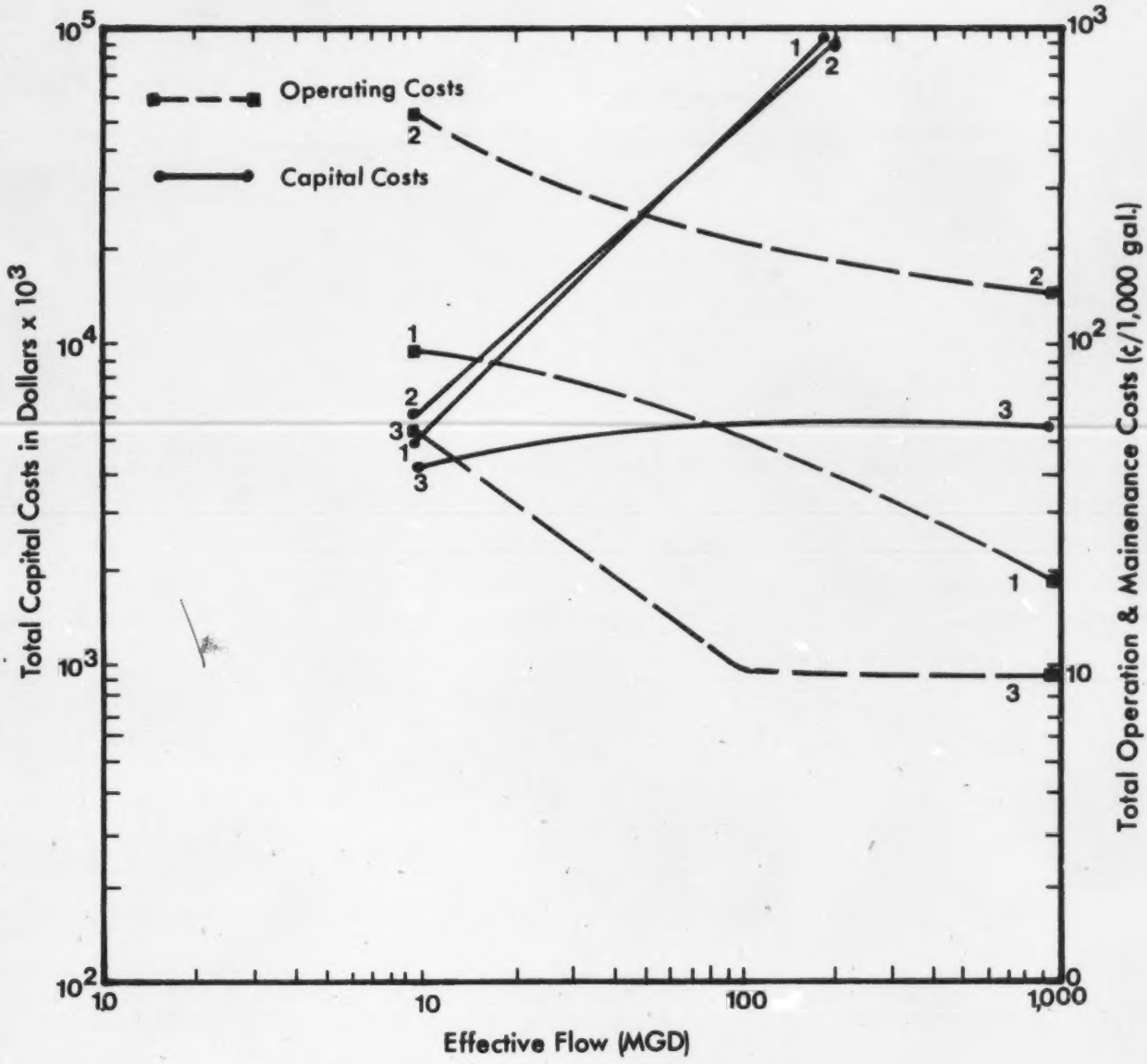
Capital and operating costs vs. flow rates: In Module 4, "Treatment Systems, Effluent Qualities, and Costs", land treatment was compared to tertiary treatment in terms of efficiency and cost. A more precise feeling for the relative numbers involved in tertiary treatment and land application cost comparison is obtained from Figures 8 and 9. Those values summarize information about a variety of tertiary treatment and land application options. While the options given in Figure 8 may be familiar, examine the options of Figure 9 more closely. Note that the costs for rapid infiltration are consistently lowest at all flows and that the application rate is 12 in./wk (30 cm/wk) compared to 2 in./wk (5 cm/wk) for other options. Costs related to the remaining land application options are competitive with each other although spray irrigation tends to be higher priced overall.

Break-point issues: The important point for this course, however, is the comparison between costs of pretreatment plus land application with costs of physical-chemical tertiary treatment. From what has been said earlier (especially with regard to Figure 7), primary pretreatment plus land application normally is cheaper than tertiary treatment. However, when secondary pretreatment costs are combined with land application, total costs begin to approach and sometimes exceed those of physical-chemical tertiary treatment. Costing factors which favor pretreatment-land application to tertiary treatment (or vice cersa) can arise from very site specific situations, some of which are discussed below.

Most important is to compare costs of pretreatment plus land application with costs of physical-chemical tertiary treatment.

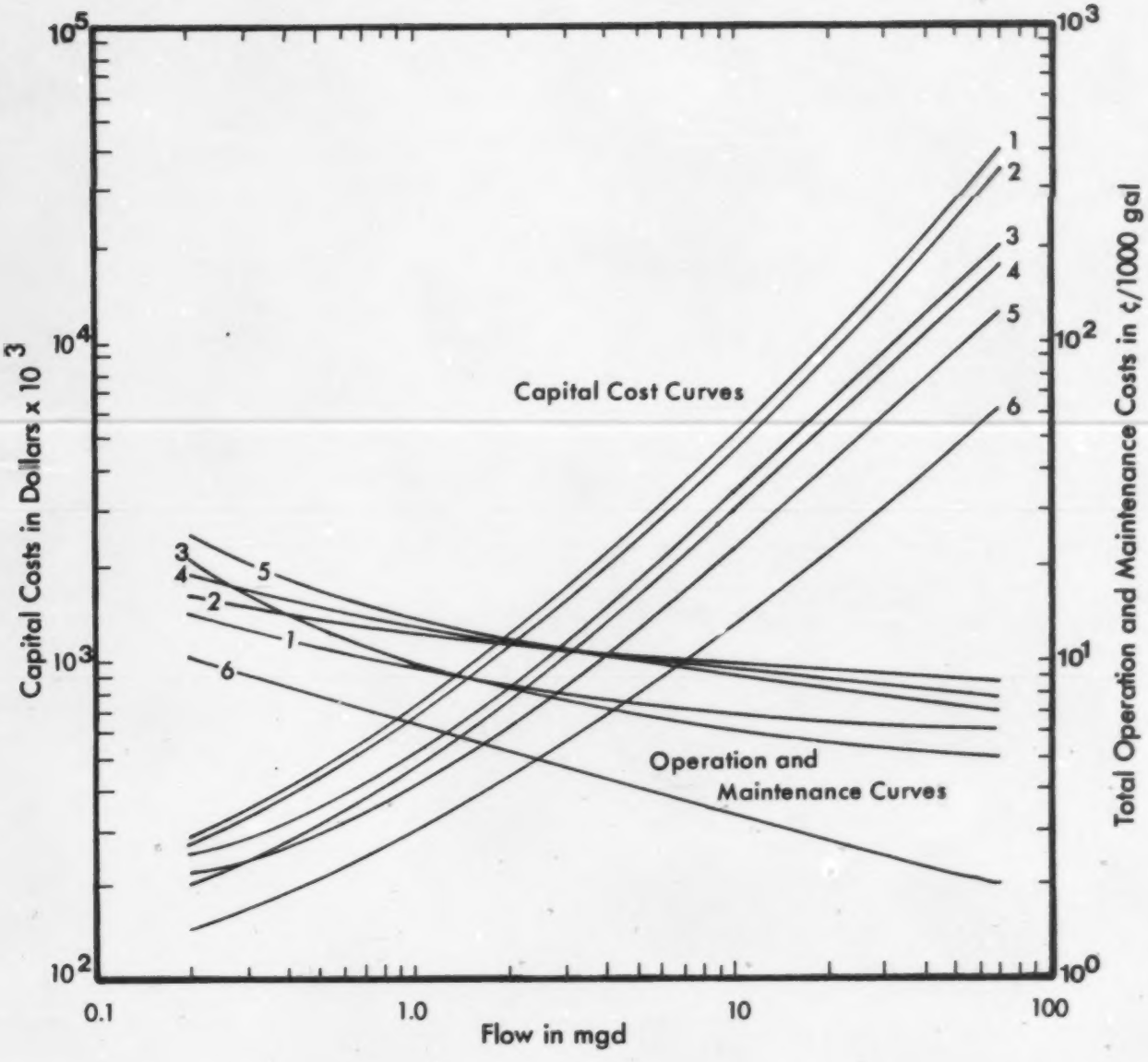
If land values are higher than the $500/acre assumed in the data of Figure 7 or if prevailing laws force the purchase of extra large buffer zones around a given site, land application would become less cost-effective compared to conventional secondary treatment.

If land values are higher than $500 an acre or if laws force the purchase of extra large buffer zones around a site, the cost-effective advantage of land treatment would be lessened.




1. Nitrification/Dentrification with Sludge Digestion & Land Spreading.
2. Clarification/Carbon Absorption with Sludge Recalcination, Digestion & Land Spreading.
3. Filtration/Carbon Absorption with Incineration of Chemical Sludge.

Figure 8. Comparative capital costs and operation-maintenance costs for various tertiary treatment regimes (adapted from Battelle Report, 1974).




1 Spray Irrigation, 2 in./wk, Solid Set, Buried, Woodland
2 Spray Irrigation, 2 in./wk, Solid Set, Buried, Crop
3 Overland Flow, 2 in./wk
4 Spray Irrigation, 2 in./wk, Center Pivot
5 Surface Irrigation, 2 in./wk, Ridge and Furrow
6 Infiltration/Percolation, 12 in./wk, 50 ft Recovery Wells

Figure 9. Comparative capital costs and operation-maintenance costs for various land application regimes (adapted from Pound, et al. 1975, pp. 38-49).

Along with land values, transportation of material from its source to the land application site must be considered. In general, land values decrease with distance from municipal areas while transportation costs increase. In Module 4, "Treatment Systems, Effluent Qualities and Costs", this factor was addressed with the aid of the diagram reproduced here as Figure 10. Even though that presentation is merely an idealized version, it conveys the relative narrowness of optimum conditions for minimum transportation/land cost ratios.

The pumping head factor may be determined by the topography of a site. Also, the design requirements of spray rigs may require high pressure pumping. The costs for distribution pumping at 50, 150, and 300 ft total heads are given in Figure 11.

Certain construction factors may appear which interfere with cost effectiveness of land application systems. For example, in Figure 12 attention is given to pipe costs, arrangements, and spacings for spray irrigation systems. In each case, the costs involved for even the most extreme situations amount to only a few thousand dollars. That is only a small fraction of the system cost, but again the margin for cost effectiveness is narrow and may be closed by such site specific requirements.

Recovery wells may be needed, especially in rapid infiltration systems. In general, flooding is much cheaper than spraying, but in some cases there may be the cost of preparing recovery wells. Some comparative costs for recovery wells are given in Figure 13.

Flooding of wastewater is generally cheaper than spraying of wastewater.

Underdraining may be needed for systems which cannot accept the hydraulic loading imposed on them without some method of preventing soil waterlogging. Some representative costs for underdraining are given in Figure 14.

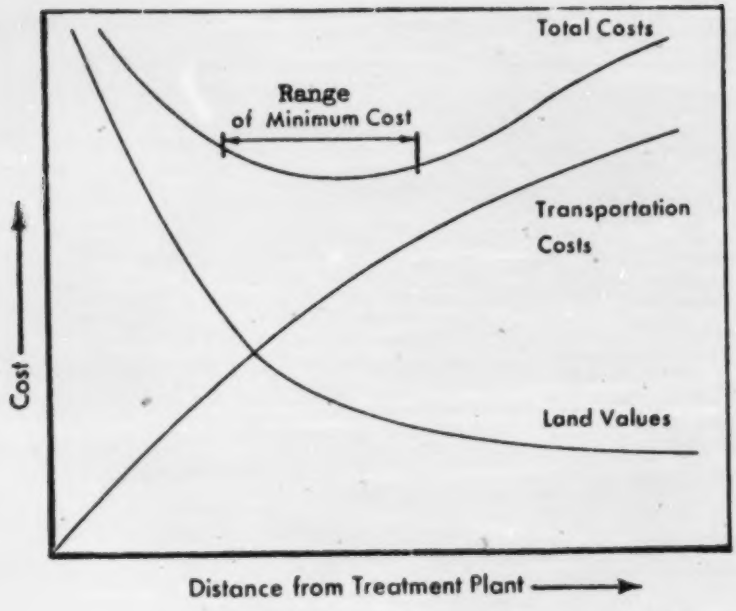
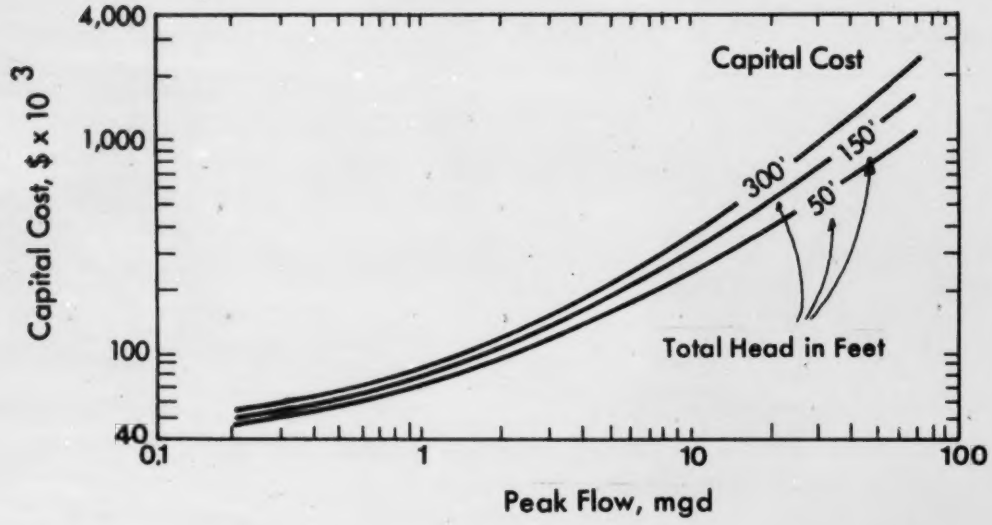



Figure 10. Minimum costs represent a tradeoff between land values and transportation costs (Battelle Report, 1974, p. 157).



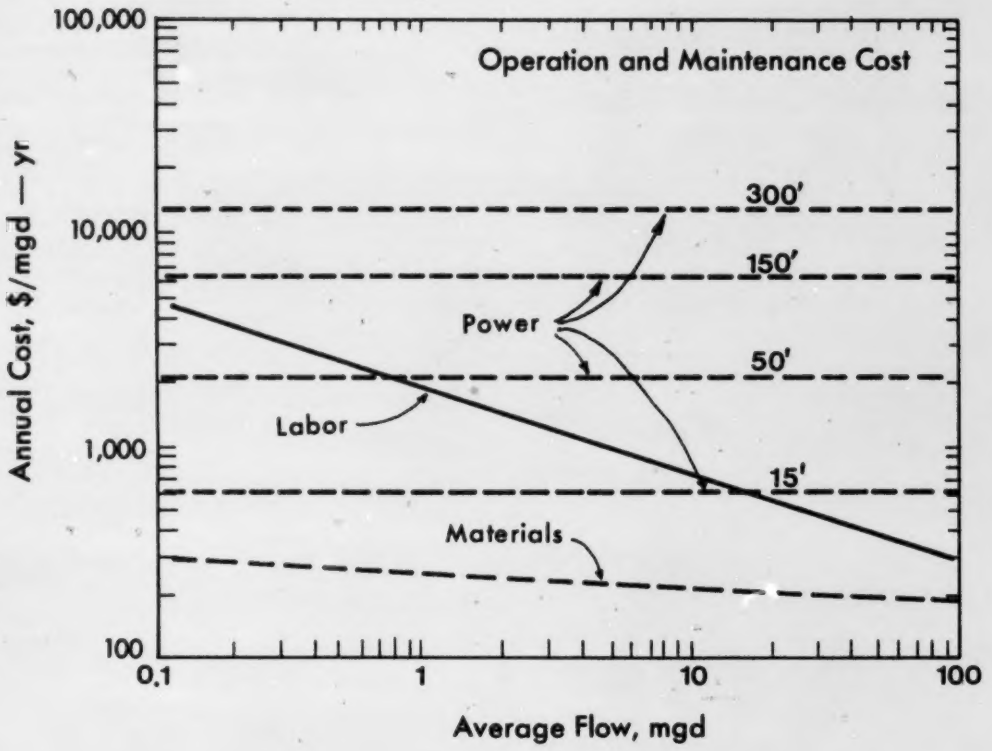




Figure 11. Pumping costs increase with head (Pound and Crites, 1975, p. 103).

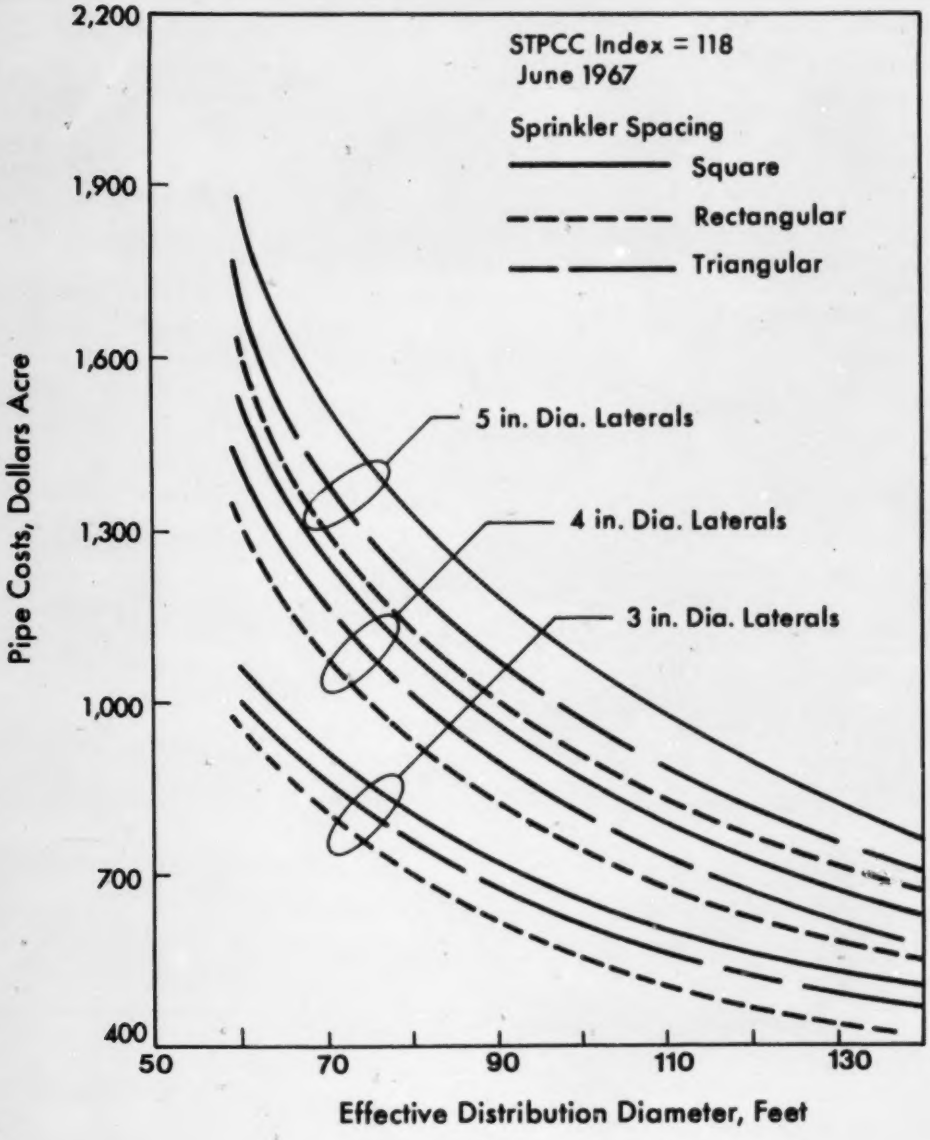



Figure 12. Pipe costs for spray irrigation decrease with smaller diameter pipes and larger area served by a given pipe (Pound and Crites, 1975, p. 146).

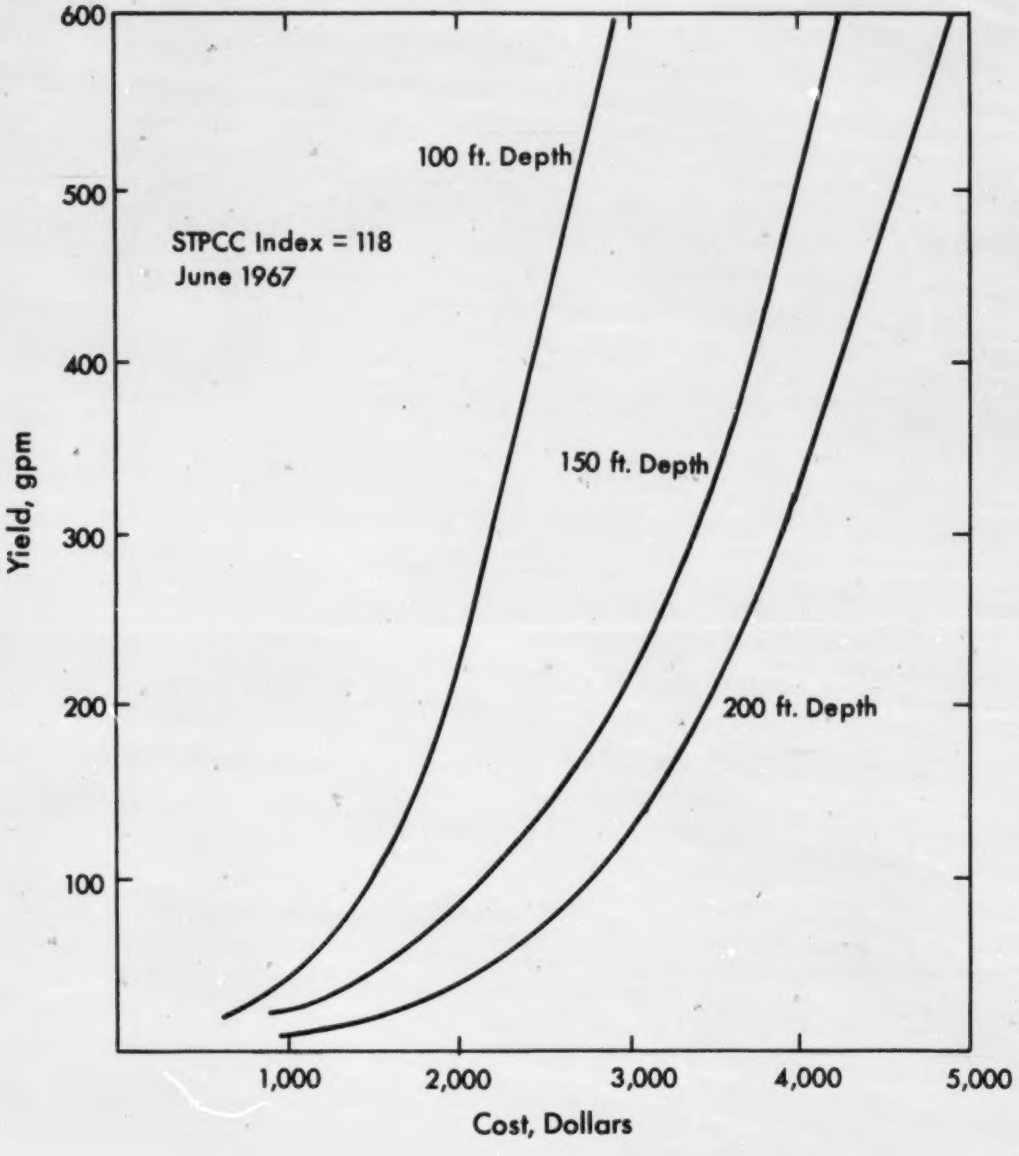
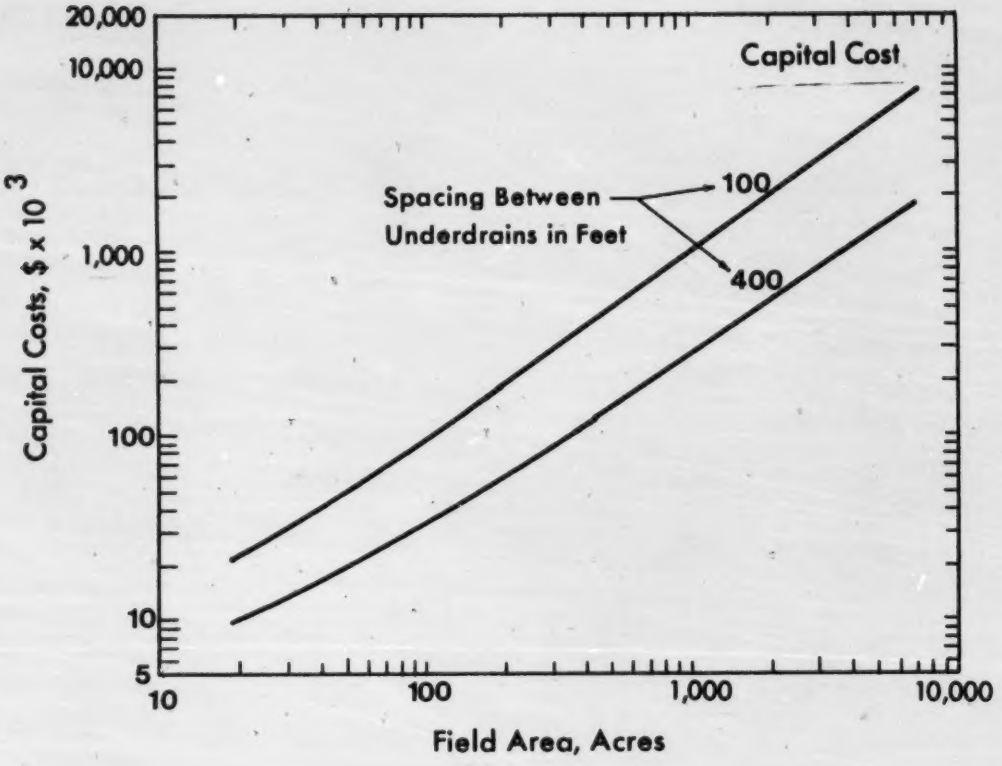



Figure 13. Costs for recovery wells increase with depth and expected yield (Pound and Crites, 1975, p. 154).



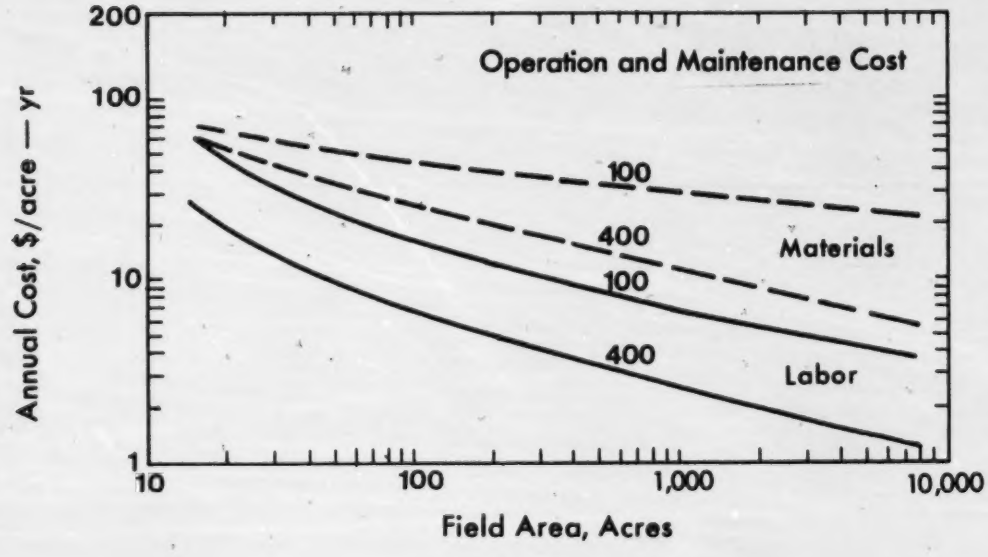




Figure 14. Underdrain capital costs increase with the area served while operation and maintenance costs decline (Pound and Crites, 1975, p. 105).

Monitoring systems are dictated by both prudence and legal requirements. Common monitoring devices include suction lysimeters, surface grab samples, or monitoring wells. Total costs depend on both the type of installation(s) used and their numbers. A quick overview of one such cost, monitoring wells, is given in Figure 15.

Total costs of monitoring systems depend on both the type of installation used and the number of devices used in the system.

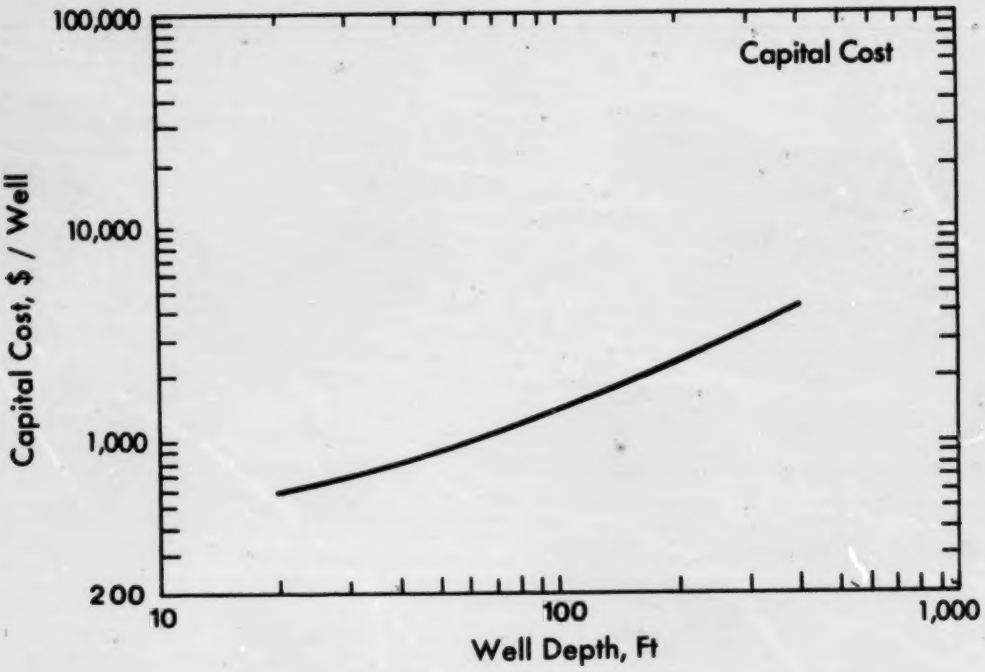
Agricultural profit is often proposed as a source of income sufficient to offset a significant proportion of operation costs. Certainly there is no doubt that the value of agricultural products will increase in the future, but that does not mean that crops will offset operational costs in land application in all cases. Lands irrigated by wastewaters require careful husbandry to produce high cash crops. That requires talent and capital which many municipalities are unable or unwilling to invest. Even forage crops require harvesting and other care which reduce the magnitude of profit. Nevertheless, some profit from crops may be realized with careful planning. Also, water and sludges may be sold where there is demand. However, the usual experience is that any income represents only a partial recovery of costs.

Although some profit from crops may be realized with careful planning of the land application system, any income represents only a partial recovery of costs.

The careful selection of system components is one of the more effective activities entering into break-point decisions. That was emphasized at the start of this module but deserves another look. A designer who is obliged to include secondary pretreatment before land application may opt for lagooning or aerated lagoons rather than, say, an activated sludge pretreatment, provided that the discharge from the lagoons satisfies regulatory agency requirements for secondary treatment prior to land application.

The careful selection of system components is one of the more effective activities entering into break-point decisions.

The cost effectiveness of waste treatment systems must be reported at some point in the earlier planning stages. Such cost effectiveness is defined in Federal Register (Quarles, 1973).



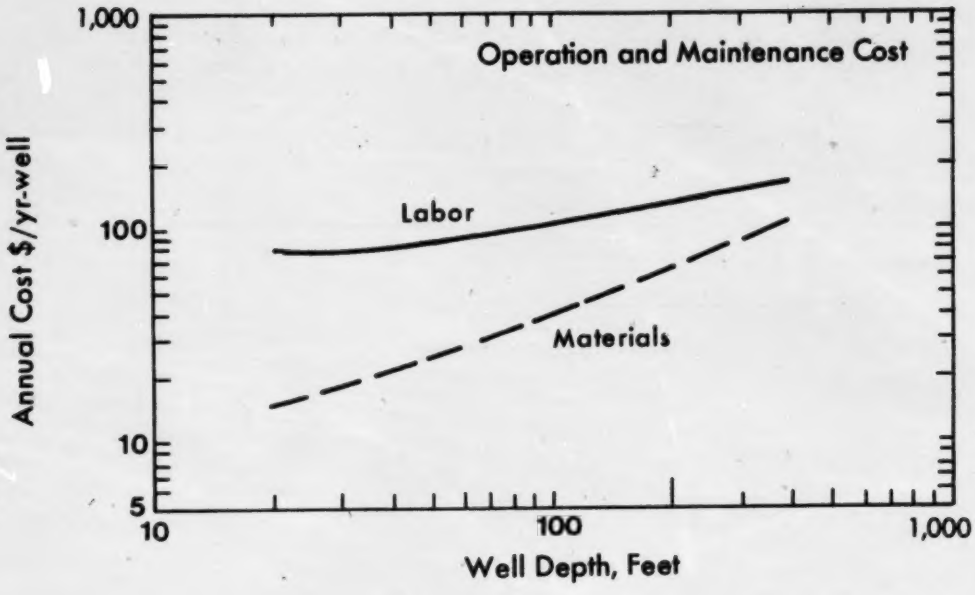




Figure 15. Costs of monitoring wells depend on depth (Pound and Crites, 1975, p. 117).

Summary of Generalizations

A waste treatment system which is to be built to achieve high quality effluent must be designed to site specific limitations. Few effective rule-of-thumb generalizations can be formulated. However, some such generalizations are useful in the initial planning stages.

Source to site distance limits: One obvious place to begin to look for some generalization would be in the distance from waste source to land application. In cases where transmission costs are very high, land application has a substantially reduced cost effectiveness versus tertiary treatment. Would it therefore be possible to state that, say, a 10 mile transmission is prohibitive - or 15 miles or 20 miles?

By returning to Figure 10, the implausibility of a general rule in this area becomes apparent. The cost of a system depends on two functions: land value and transportation. Each of these are under the economic constraints of the community. In larger communities land values may remain high for many miles in all directions, diminishing or even obscuring any optimum cost range. Yet, while a community may find tertiary treatment for wastewaters to be cost-effective, long range transport of sludges may be economically acceptable. Thus, Chicago can send its sludges many miles downstream for a land reclamation project, or Philadelphia can ship sludge some 150 miles away to an ocean dumping site. Small communities may not be able to transport waste matter more than a half dozen miles or so without losing cost-effectiveness. The cost-effectiveness of the transmission distance for sludges and wastewaters depends considerably on local conditions. However, for any given situation, estimates should be available for both land and transportation or piping costs.

The optimum cost for a system depends on land value and transportation; each of these factors are determined by the economic constraints of the community.

To approach the problem of pumping costs for land application systems, assume that the values presented in Figure 7 are representative of a given system. A system

employing primary treatment plus spray irrigation would involve a capital outlay of 23.4¢/1000 gal. Therefore, given the above pretreatment and application combinations, costs to overcome a head disadvantage may amount of 10¢/1000 gal. (or some 43% of the total land treatment capital costs) before losing its cost advantage to tertiary treatment. However, a trickling filter-spray irrigation combination costing 29¢/1000 gal. could tolerate a head disadvantage of only some 16.5% of the total capital cost before losing cost-effectiveness to tertiary treatment. This cost differential is equivalent to a pumping head of about 300 feet of water.

Operating expenses are more critical in this matter than capital expenses. Notice that a combination of the operating expenses of preliminary treatment and spray irrigation would be about 12¢/1000 gal. less than operating costs for tertiary treatment. The operating costs of the trickling filter and spray irrigation combination would be 3.1¢/1000 gal. in excess of tertiary treatment.

A land application system having any substantive pumping requirements faces a serious operational cost disadvantage.

Land application costs: A third question which may be asked concerns the relative costs of the various land application regimes.

Evidence from Figures 7 and 9 suggest that rapid infiltration would be the least costly system to construct and operate. But rapid infiltration systems require very specific soils (high infiltration-percolation) and deep water tables. It may be possible to modify marginally acceptable sites by underdraining or even by using a series of recovery wells. But both systems are costly (Figures 13 and 14). Again, the cost margin is narrow and a final decision may depend on yet other site-specific issues.

Evidence suggests that rapid infiltration is the cheapest application regime but requires highly specific soil conditions.

Volume of flow: A fourth area of interest is the effect of volume on the feasibility of land application.

If there is some costing limitation to land application at some volume of flow, a point should appear in land application cost (Figure 9) where costs climb prohibitively with respect to tertiary treatment (Figure 8).

Notice, however, that no such limiting point is apparent. For 0.1 to 1 mgd flows, capital costs of land application run from about $\$1.5 \times 10^5$ to $\$7 \times 10^5$. At these low flows, land application is distinctly advantageous and many land application systems of that approximate range of flow are built. Flow rates for 1 to 10 mgd have capital costs running from about $\$3 \times 10^5$ to $\$5 \times 10^6$ for land application and $\$4 \times 10^6$ to $\$6.5 \times 10^6$ for tertiary treatment (@ 10 mgd). In general, land application tends to maintain its cost advantage through the range of wastewater flows.

Examination of operating costs reveals that with increasing effective flow, operating costs for land application remain under those for tertiary treatment, at least up to 100 mgd. That makes it even less likely that cost-effective limitations for land application systems are related to an increase in volume of wastewater handled.

Even when effective volume of flow is increased, operating costs for land application remain less than those for tertiary treatment, at least up to 100 mgd

Specific Cost Estimates Depend on Valid, Current Data

Available literature: Engineering proposals will most often be evaluated on the basis of an economic comparison with alternatives which are also technically capable of achieving the project goals. The problem faced by land treatment designers is the same as that for designers of other engineered systems - obtaining valid, up-to-date cost data. The references listed on the next page should be adequate to provide land treatment cost data and comparison with "conventional" alternatives. This list is not meant to be complete. Other references are available and more will be forthcoming. The designer should keep abreast of the materials on costing being produced by EPA, Corps of Engineers and other sources in order to maintain an up-to-date cost reference file, to be used in conjunction with data from past experience of his firm or agency. The references given here meet the "criteria for selecting

Land treatment designers should keep abreast of all costing materials published by EPA and other sources.

literature" given in the first section of this module. The graphs and charts excerpted from some of these references in the section "General Overview of Relative Costs" will suggest possible uses of the references cited.

A list of some useful cost references for land treatment and conventional systems is as follows (complete titles, etc. will be found in the Bibliography):

- Battelle Institute, 1974. "Municipal Sewage Treatment" - Performance as well as cost comparisons of eleven wastewater treatment strategies, some including land application, and twelve sludge handling options. Also, transportation costs and other data.
- Pound, Crites, and Griffes, 1975. "Costs of Wastewater Treatment by Land Application" - Costs for all phases of land application systems for preliminary and detailed cost estimates. Keyed to EPA Construction Cost Index.
- Pound, Crites, and Smith (1975). "Cost Effective Comparison of Land Application and AWT" - Variables included are site conditions, distance to site, flows, and land prices.
- DiGregorio, 1968. "Cost of Wastewater Treatment Processes" - Conventional preliminary, primary, secondary, sludge dewatering, three forms of tertiary and package plants.
- Smith and McMichael, 1969. "Cost and Performance of Tertiary Processes" - Most standard tertiary processes.
- VanNote, et al., 1975. "Guide to Selection of Cost-Effective Systems" - Costs of unit processes and systems based on them and methods of determining cost-effectiveness.

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# APPENDIX

The Appendix contains two optional exercises in the use of some of the reference materials mentioned in the text of the module.

The first exercise (Appendix A) is a sample costing problem, which includes a worksheet and an answer sheet. The Sample Problem requires the use of two references:

- Battelle Report ("Municipal Sewage Treatment - A Comparison of Alternatives", 1974).
- Pound Report ("Costs of Wastewater Treatment by Land Application", 1975).

The second exercise (Appendix B) is a "self evaluation" of the reader's familiarity with the two references listed above, by answering a variety of questions pertaining to data found in them.

## Appendix A

### SAMPLE PROBLEM

This is a problem for estimating the cost of a Land Application System. This part of Module 10 is optional.

Determine preapplication costs using the data and procedures outlined in the Battelle Report and Stage I costs using the Pound Report.

Answers (with some comments) are given. Note that the Battelle Report and Pound Report data sheets are attached for the convenience of the reader.

A small municipality in a northern latitude has been urged to treat its estimated 1.2 mgd sewage flow by activated sludge with discharge to land through center pivot spray irrigation applied at 1.8 in. per day. Sludge is to be thickened by flotation, digested, and spread onto the land. The prevailing construction index (EPA) is 180, the local multiplier is 1.6. Land values at the proposed site are $600/acre, power costs are 0.035¢ /kwh, chlorine costs $0.08 lb. The land site is 2.4 miles from the treatment plant and 20 ft elevation. Sludge is to be transported to local farms for a round trip of 6 miles at $0.12/ton-mile round trip. Amortization will be over 20 years at 10%. The amortization factor will be 0.117. Land application will be for 40 weeks. Storage in a lined reservoir will be needed. Local labor costs are $7.50 per hour. Spraying will be done on grasses and a 200 ft buffer zone is required.

## SAMPLE WORKSHEET

### Assumptions

Plant Type -

Flow Rate -

Prevailing Construction Index - EPA -

ENR -

Local Multiplier -

Local Land Value - $ /acre

Local Cost of Labor - $ /hr (weighted average for operating labor and supervision)

Local Cost of Power - $ /kW-hr

Prevailing Cost of Chemicals

_____ @ $_____/lb

_____ @ $_____/lb

_____ @ $_____/lb

_____ @ $_____/lb

Transport Distance for Sludge miles round trip

Transport Cost for Sludge $/ton-mile

Transport Distance for Effluent miles

Transport Cost for Effluent $/1000 gal.

Amortization Basis _____%

_____years

Factor _____

### Capital Costs

Estimated Cost

1. Running Total Base Cost on Profile Sheet $_____ for _____ flow
2. Flow Change Multiplier = _____: Flow Adjusted Cost = $_____
3. National Cost Factor = ( /175) = _____

   Price Index Adjusted Cost = $_____
4. Local Multiplier = $_____
5. Total Adjusted Cost = $_____
6. Base Land Requirement from Profile Sheet _____ acres
7. Land Requirement Multiplier = (____/_____)$^{.6}$ = _____
8. Adjusted Land Requirement = _____ x _____ = _____ acres
9. Adjusted Land Costs = _____ x _____ = $_____
10. Total Capital Expenditures = $_____

## Operating Costs

### Labor

1. Base Labor Requirement on Profile Sheet _____ man years
2. Labor Multiplier (_____/_____)$^{.58}$ = _____ man years
3. Adjusted Labor Requirement = _____ man years

### Electric

4. Base Electrical Requirement on Profile Sheet _____ kW-hr/day
5. Electrical Multiplier = (_____/_____)$^{.55}$ = _____
6. Adjusted Electrical Requirement = _____ x _____ = _____ kW-hr/day

### Chemical

7. Base Chemical Requirements on Profile Sheet _____ lb/day
8. Chemical Multiplier = (_____/_____)$^{1.0}$ = _____
9. Adjusted Chemical Requirement = _____ x _____ = _____ lb/day

### Fuel

10. Base Fuel Requirement on Profile Sheet _____ Btu/day
11. Fuel Multiplier = (_____/_____)$^{1.0}$ = _____
12. Fuel Requirement = _____ x _____ = _____ Btu/day

### Sludge

13. Base Quantity of Sludge Requiring Transportation _____ Tons/day
14. Sludge Multiplier (_____/_____) = _____
15. Adjusted Quantity of Sludge Requiring Transportation _____ Tons/day
16. Volume of Effluent Requiring Transportation _____ 1000 gal/day

### Summation

17. Daily Labor Cost _____ x _____ x 8 = $_____/day
18. Daily Electrical Cost _____ x _____ = $_____/day
19. Daily Chemical Cost _____ x _____ = $_____/day
20. Daily Fuel Cost _____ x _____ = $_____/day
21. Daily Solids Transportation Cost _____ tons/day x _____ tons/mi x _____ mi = $_____/day
22. Total Daily Cost _____ + _____ + _____ + _____ + _____ = $_____/day
23. Total Cost/1000 gal. _____ ÷ _____ = $_____/1000 gal.
24. Cost for Effluent Transportation _____ x _____ x _____ = $_____/1000 gal.
25. Adjusted Operating Cost _____ + _____ = $_____/1000 gal.
26. Adjusted Amortization Cost @ 10% for 20 Years (_____ x _____) ÷ (365 x _____) = $_____/1000 gal.
27. Total Adjusted Operating Cost _____ + _____ = $_____/1000 gal.

Table 3

Sample Stage I Cost Calculation Sheet

Alternative No. _____ Average Flow _____ mgd

Type of System _____ Analysis Date _____

| Cost Component | Total Capital Cost $ | Amortized Capital Cost, ¢/1,000 gal. | O&M Cost, ¢/1,000 gal. | Total Cost, ¢/1,000 gal. |
|---|---|---|---|---|
| Preapplication treatment | | | | |
| _____ | _____ | _____ | _____ | _____ |
| _____ | _____ | _____ | _____ | _____ |
| _____ | _____ | _____ | _____ | _____ |
| Transmission-conveyance | | | | |
| _____, _____ mi | _____ | _____ | _____ | _____ |
| Transmission - pumping | _____ | _____ | _____ | _____ |
| Storage period | | | | |
| _____ wks | _____ | _____ | _____ | _____ |
| Application systems | | | | |
| _____ | | | | |
| @ _____ in./wk | _____ | _____ | _____ | _____ |
| Underdrains | | | | |
| SUBTOTAL, BASE DATE[a] | _____ | _____ | _____ | _____ |
| Trend factor[b] | _____ | _____ | _____ | _____ |
| SUBTOTAL, ANALYSIS DATE | _____ | _____ | _____ | _____ |
| Crop revenues | | | (_____) | (_____) |
| Land cost _____ acres | _____ | _____ | _____ | _____ |
| @ _____ per acre | | | | |
| TOTAL COST | _____ | _____ | _____ | _____ |

a. February 1973

b. Trend factor = EPA Sewer Construction Cost Index for analysis date at appropriate location ÷ 194.2.

Sample Worksheet (From the Battelle Report, pp. 151-154)

Assumptions

Plant Type - Strategy #6, Sludge Option 5 (Battelle Rpt. p.92,94)

Flow Rate - 1.2 mgd

Prevailing Construction Index - EPA - 180
ENR -

Local Multiplier - 1.6

Local Land Value - $600/acre

Local Cost of Labor - $7.50/hr (weighted average for operating labor and supervision)

Local Cost of Power - $0.035/kW-hr

Prevailing Cost of Chemicals

Chlorine @ $ 0.08 /lb

_____ @ $ _____ /lb

_____ @ $ _____ /lb

| | | |
|---|---|---|
| Transport Distance for Sludge | 10 | miles round trip |
| Transport Cost for Sludge | $ 0.12 | $/ton-mile |
| Transport Distance for Effluent | 2.4 | miles |
| Transport Cost for Effluent | N.A. | $/1000 gal. |

Amortization Basis 10 %

20 years

Factor 0.117

Capital Costs — Estimated Cost

1. Running Total Base Cost on Profile Sheet $ 4,210,000 for 1 mgd flow
2. Flow Change Multiplier = $(1.2/1)^{0.6}$=1.116 : Flow Adjusted Cost = $ 4,698,360
3. National Cost Factor = (180/175) = 1.029
   Price Index Adjusted Cost = $1.029 x 4,698,360 = $4,832,599
4. Local Multiplier = 1.6
5. Total Adjusted Cost = $1.6 x 4,832,599 = 7,732,158
6. Base Land Requirement from Profile Sheet 19 + 15.4 = 34.4 acres
7. Land Requirement Multiplier = ( 1.2 / 1 )$^{.6}$ = 1.116
8. Adjusted Land Requirement = 1.116 x 34.4 = 38.4 acres
9. Adjusted Land Costs = 38.4 x $600 = $ 23,034
10. Total Capital Expenditures = $ 7,755,192

## Operating Costs

### Labor

1. Base Labor Requirement on Profile Sheet 3.2 + 7.9 + 7.9 = 19 man years
2. Labor Multiplier ( 1.2 / 1 )$^{.58}$ = 1.112 man years
3. Adjusted Labor Requirement = 1.112 x 19 = 21.12 man years

### Electric

4. Base Electrical Requirement on Profile Sheet 1270 + 373 + 1210 = 6214 kW-hr/day
5. Electrical Multiplier = ( 1.2 / 1 )$^{.55}$ = 1.105
6. Adjusted Electrical Requirement = 1.105 x 6214 = 6869 kW-hr/day

### Chemical

7. Base Chemical Requirements on Profile Sheet 670 + 58 = 728 lb/day
8. Chemical Multiplier = ( 1.2 / 1 )$^{1.0}$ = 1.2
9. Adjusted Chemical Requirement = 1.2 x 728 = 874 lb/day

### Fuel

10. Base Fuel Requirement on Profile Sheet N.A. Btu/day
11. Fuel Multiplier = ( N.A. / ) $^{1.0}$ =
12. Fuel Requirement = N.A. x = Btu/day

### Sludge

$\frac{10,800 + 12,500 + 14,000}{2,000}$ = 18.6

13. Base Quantity of Sludge Requiring Transportation Tons/day
14. Sludge Multiplier ( 1.2 / 1 ) = 1.2
15. Adjusted Quantity of Sludge Requiring Transportation $\frac{18.6 \times 1.2}{22.4}$ = Tons/day
16. Volume of Effluent Requiring Transportation N.A. 1000 gal/day

### Summation

17. Daily Labor Cost 21.12 x 7.50 x 8 = $ 1267.20 /day
18. Daily Electrical Cost 6869 x 0.035 = $ 240.42 /day
19. Daily Chemical Cost 874 x 0.08 = $ 69.92 /day
20. Daily Fuel Cost N.A. x = $ - /day
21. Daily Solids Transportation Cost 22.4 tons/day x $0.12 tons/mi x 6 mi = $ 16.13 /day
22. Total Daily Cost $1267.20 + $240.42 + $69.92 + N.A. + $16.13 = $ $1593.67 /day
23. Total Cost/1000 gal. $1593.67 ÷ 1200 = $ 1.33 /1000 gal.
24. Cost for Effluent Transportation N.A. x x = $ /1000 gal.
25. Adjusted Operating Cost 0.00 + 1.33/100 gal = $ 1.33 /1000 gal.
26. Adjusted Amortization Cost @ 10% for 20 Years (7,755,192 x 0.117) ÷ (365 x 1200) = $ $2.07 /1000 gal.
27. Total Adjusted Operating Cost $1.33 + $2.07 = $ 3.47 /1000 gal.

Table 3

Sample Stage I Cost Calculation Sheet

Alternative No. 1 Average Flow 1.2 mgd

Type of System SPRAY IRRIGATION, PIVOT Analysis Date -

| Cost Component | Total Capital Cost $ | Amortized Capital Cost, c/1,000 gal. | O&M Cost, c/1,000 gal. | Total Cost, c/1,000 gal. |
|---|---|---|---|---|
| Preapplication treatment | 7 755 192 | 149.9 | 133 | 347.00 |
| | | | | |
| | | | | |
| Transmission-conveyance FORCE MAIN, 2.4 mi | (86000 x 2.4 =) 206 400 | (1.8 x 2.4 =) 4.32 | (0.028 x 2.4 =) 0.067 | 4.39 |
| Transmission - pumping (1) | 210 000 | 4.50 | 2.3 | 6.80 |
| Storage period 12 wks | (160000 x 2.2 =) 352 000 | (3.00 x 2.2=) (2) 6.60 | (0.43 x 2.2=) 0.946 | 7.55 |
| Application systems (3) SPRAY, PIVOT @ 1.8 in./wk | 500 000 | 9.0 | 10.2 | 19.20 |
| Underdrains | | | | |
| SUBTOTAL, BASE DATE[a] | 9 023 592 | 174.3 | 146.5 | 384.94 |
| Trend factor[b] (180) | 0.93 | 0.93 | 0.93 | 0.93 |
| SUBTOTAL, ANALYSIS DATE | 8 391 941 | 162.1 | 136.2 | 357.99 |
| Crop revenues | | | ( none ) | ( none ) |
| Land cost 380 acres @ $600 per acre | 22 800 | 2.93 (4) | - | 2.93 |
| TOTAL COST | 8 691 941 | 165.03 | 136.2 | 360.92 |

a. February 1973

b. Trend factor = EPA Sewer Construction Cost Index for analysis date at appropriate location ÷ 194.2.

1. The site is only 20 ft elevation, but the pumping head must be much greater to obtain the desired spray. Using these data derived for an effective head of 150 will give a spray head of 150-20=130 ft or somewhat less than design specs.



(continued on next page)

Table 3 (continued)

2. See comment, p. 30: for full lining of storage, multiply by 2.2.

3. Note that these curves require EFFECTIVE FLOW. The effective flow of this system is: (52/40) x 1.2 = 1.56 MGD. This is caused by less than full year application.

4. Amortized cost = 0.0154 x (tot. capital cost of land/average design flow).

## Appendix B

### A SELF EVALUATION

(Optional)

The object of these questions is to obtain some indication of how familiar the reader is with the literature in terms of both locating pertinent information and using tables, nomograms, graphs, and other aids.

Answers are provided.

1. What is meant by the term "strategy" as used in both Battelle and Pound?

   _____

   _____

2. What is meant in Pound, et al. by "Stage I" and "Stage II"? _____

   _____

   _____

3. Are schematics provided for specifying sludge options in the Battelle report? If so, how many options are specified? _____

4. Specify energy requirements (kWh), total capital costs, and total operating costs for a trickling filter with discharge to surface water, sludge handling by gravity, digestion, and land spreading, for 1 mgd, 10 mgd, and 100 mgd using the Battelle Report.

| | Energy (kWh) | Total Cap Cost | Total Op Cost |
|---|---|---|---|
| 1 mgd | _____ | _____ | _____ |
| 10 mgd | _____ | _____ | _____ |
| 100 mgd | _____ | _____ | _____ |

5. How much land is required for a 1 mgd flow at an application of 2.0 in./week for 32 weeks of the year? Answer for conditions of no buffer zone and 200 ft buffer zone. _____

6. What is the capital cost in $/LF of a 10 inch gravity pipe buried to a depth of 9 ft under wet conditions? _____

7. Assuming a land value of $500 per acre, what would land costs be for a 5 mgd system operating 40 weeks at 1.5 in./week? _____

   _____

A SELF EVALUATION (continued)

8. Using the quick comparisons given in the Batelle Report, determine the following:

   a) Are the labor requirements for a 10 mgd operation, employing strategy #10, greater or less than for a similar 1000 mgd plant? _____

   _____

   b) Which three strategies produce the greatest volume of sludge (identify by number)? _____

   _____

   c) Which strategy removes the most phosphorus? _____

   _____

9. Give two methods of updating cost estimates. _____

   _____

   _____

1. A "strategy" is a system of facilities which will provide some stated degree of treatment of wastewaters and sludges (Battelle, pp. 4-12)
2. "Stages" refer to degrees of complexities of listing the general components of Land Application Systems. Stage I has five components: Preapplication treatment, transmission, storage, application systems, and recovery of renovated water. Stage II has seven components: preapplication treatment, transmission, storage, field preparation, distribution, recovery of renovated water, and additional costs. (Pound, et al. pp. 24-61).
3. Twelve sludge options, with schematics, are specified in Battelle, pp. 13-24.
4. From Battelle, pp. 78-81 (Strategy #3).

| | Energy (kWh) | Tot Cap Cost | Tot Op Cost |
|---|---|---|---|
| 1 mgd | 450 | $ 1.24-1.29x$10^6$ | 4.8-7.0¢/1000 gal. |
| 10 mgd | 1774 | $ 4.14-4.32x$10^6$ | 1.8-2.8¢/1000 gal. |
| 100 mgd | 4790 | $27.8 -28.2x$10^6$ | 2.2-2.5¢/1000 gal. |

5. No buffer zone: 250 acres.
   200 ft buffer zone: 325 acres (Pound, et al. p. 26 - why is the nomogram on p. 63 inappropriate for answering this problem?).
6. See Pound, et al. pp. 72-73. Cost under normal conditions would be about $12/LF, but the wet conditions require an adjustment factor (given on p. 72) of 1.20, therefore capital cost = 1.20 x $12/LF + $14.40/LF. (Why was the information on pages 32-33 not used to answer this question?).
7. Using Pound, et al. pp. 62-63, total acres needed would be about 1,100 acres @ $500/acre = $550,000.
8. Battelle Report:
   a. Page 28, Figure 22-A: higher.
   b. Page 30, Figure 24-E: strategies 8, 9, and 10.
   c. Page 31, Figure 25-B: none of the strategies remove phosphorus. They all send the same relative amount for disposal.
9. Engineering News Record and EPA's Sewage Treatment Plant Construction Cost Index (Battelle Report, p. 143, second to last paragraph).

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PROFESSIONAL STAFF

| | |
|---|---|
| W. W. Clarkson, Research Associate | Agricultural Engineering |
| G. S. Friedman, Research Associate | Education |
| A. C. Plescia, Production Coordinator | Agricultural Engineering |

PRINCIPAL FACULTY PARTICIPANTS

| | |
|---|---|
| W. J. Jewell, Agricultural Engineering | Principal Faculty Advisor |
| R. C. Loehr, Environmental Studies Program | Project Coordinator |
| J. D. Novak, Education | Principal Faculty Advisor |
| E. L. Stone, Agronomy | Principal Faculty Advisor |

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D. F. Smith, Agricultural Engineering
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